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APPLE SPRAYING EXPERIMENTS IN 1926 AND 1927

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BULLETIN 348

APPLE SPRAYING EXPERIMENTS IN 1926 AND 1927.[1]

DONALD FOLSOM AND THEODORE T. AYERS[2]

SUMMARY

(1) Tests were made of various spray schedules, differing as to the number and dates of the applications but using the same material as a fungicide. These tests showed that the pre-pink application might reduce scab (percentage basis) without being necessary for good control, and that in one season the pre-pink, pink, 4-week, and August applications each helped to reduce scab, with less scab present as more applications were made. Here tree variation prevented a significant effect from any one application. The relative amounts of different degrees of scab injury may vary with different schedules, so that the manner of grading may determine somewhat the commercial value of any spray schedule.

(2) The preceding tests, continued into the winter, showed that scab appearing first in storage can result from infection occurring before an August application, but that when severe it is reduced considerably by an August application. Slight differences in storage temperature near 32° F. did not affect storage scab consistently. Lesions apparent at packing time did not enlarge in storage. Handling at packing time did not transmit the disease.

(3) Leaf burning in both Ben Davis and McIntosh was increased by spraying, especially in the later applications. It was aggravated by the use of a faulty spray gun. Fruit russet-

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[1]Previous experimental work of this kind is described in the Maine Agricultural Experiment Station Bulletins 189, 198, 212, 223, 240, 252, 249 (summarizing the preceding six), 271, 325, and 333.

[2]The junior author, while assistant plant pathologist at this Station, performed the experimental work following the August application of 1926 and preceding the examination of the Ben Davis fruits in 1927.

ing was more severe in Ben Davis than in McIntosh. With more spray applications fruit russeting can be increased but at the same time scab can be decreased enough more so that each spray application gives a net gain in the percentage of clean fruit.

(4) Differences in vigor, russeting, and scab, recorded for different seasons in the same plot or tree, do not necessarily follow spraying or lack of spraying for a series of years (except for McIntosh twig infection), and may occur with apparently similar spray conditions for the different seasons.

(5) The financial profit of a schedule or of any application varies with the season and with the variety. McIntosh need more spraying and can endure more, from the standpoint of the appearance of the fruit. Fruit dropping from spraying does not necessarily occur.

(6) Sulphur dust can prove disappointing, may reduce fruit scab more than leaf scab, and can increase fruit russeting significantly.

(7) A difference in spray schedule may increase leaf scab without increasing fruit scab. Among unsprayed trees, there may be an important and significant correlation between leaf scab and fruit scab.

(8) Variation among trees with respect to leaf scab can sometimes be attributed to proximity to permanent control plots. Variation with respect to leaf and fruit scab were attributable to position in the orchard, more than to differences in applications of nitrate of soda fertilizer.

(9) In McIntosh, twig infection can, and often does, cause severe infection of leaves and fruits, even in spite of the spraying of twigs and leaves. The twig pustules can, and usually do, cause infection of leaves later in the season than ascospore infection of leaves occurs.

(10) General observations and experiments in commercial orchards show that there is too much variation in spraying schedules, equipment, and other conditions to permit any generalizations with regard to scab differences. In one orchard there was a minimum of infection of unprotected control trees which probably was due to the reduction of ascospore inoculum by thorough spraying in previous seasons.

(11) The ascospores develop differently according to season and location, are more abundant in leaves bearing summer

lesions, and are not decreased by copper sulphate spraying in the fall.

(12) From a discussion, it is concluded that specific expert advice regarding the seasonal and local modification of schedules, will be either expensive or disappointing. It is also concluded that storage scab, twig infection of McIntosh, and spray injury of McIntosh are problems requiring further study before their solution is complete enough.

EFFECTS OF DIFFERENCES IN THE SPRAY SCHEDULE[8]

ON SCAB

Evidence exists that the effectiveness of spray schedules in controlling apple scab depends in part upon the number and dates of the applications. This was tested by us on Highmoor Farm in 1926 and 1927 in orchards of the Ben Davis and McIntosh varieties. The applications were made and named according to certain ideal stages in the seasonal development of the apple leaves and flowers, as follows:

Pre-pink—When some buds are pink but none have yet separated in the cluster.

Pink—When all the flower buds are pink and most are separated, or (if the pre-pink is omitted) before the flower buds open and after they are swelled so as to show a trace of pink color.

Calyx—When nearly all the petals have fallen.

Others made at stated intervals after the calyx application.

The basic conditions are important in any spray test. Dry lime sulphur 4-50 (4 lbs. in 50 gals. water) was used with 1 lb. dry lead arsenate added for the calyx and 12-day applications. The outfit in 1926 was a 200-gallon Bean gasoline-power sprayer, giving a pressure of 200-300 lbs. during spraying with two guns,

[8]Limitation of space in this bulletin forbids publishing details of methods and results, which may have its advantages. Any person's desire for more particular information on any phase of the work will be gratified with pleasure through correspondence.

and in 1927 was a Bean 300-gallon outfit maintaining 300 lbs. pressure. Thorough coverage regardless of amount was intended, and usually was secured according to general observations.

The overwintering scab fungus produces ascospores in the dead leaves on the ground. Under suitable conditions the ascospores become mature, are discharged, are blown to the new apple leaves and flowers, and begin the season's scab infection.

In 1926 in the Ben Davis orchard, microscopic examination of dead leaves showed a very small initial amount of ascospore development (ascospores mature enough to be discharged in water in a microscopic mount, only in one ascus in one of 35 leaves). Probably the small amount of ascospore inoculum ready for liberation was discharged during a certain rain occurring between the pre-pink and pink applications.

TABLE 1.

Scab on the leaves of experimental Ben Davis on Highmoor Farm, 1926

Schedule	Applications[1] and their dates						Scab on leaves[2]							
	PP	Pk	Ca	12-d	4-w	Aug.	6/2	6/17	6/29	7/13	8/11	8/25	9/22	10/8
							%	%	%	%	%	%	%	%
A	5/18	6/2	6/16	6/28	7/12	------	----	1	0	------	1	1	2	T[3]
B	------	Do	Do	Do	Do	------	----	2	1	------	4	2	2	1
C	------	Do	Do	Do	Do	8/10	----	2	1	------	4	2	2	2
D	------	Do	Do	Do	------	------	----	2	1	------	6	7	8	8
O	------	----	------	------	------	------	0	2	8	22	24	25	21	27

[1]Known respectively as pre-pink, pink, calyx, 12-day, 4-week, and August.
[2]Based on all leaves of a schedule grouped for each date, from 3 or more trees per schedule except on 6/2 and 7/13. For comparison with scab on fruit see Table 2.
[3]Trace (T) is less than ½ of one per cent.

Hundreds of the living leaves were picked from the experimental trees as representative samples and were examined carefully in the laboratory before wilting reduced the visibility of the scab spots, which in the early stages are only faint yellow areas with but few spores, if any, to produce the characteristic olive-green color familiar to growers. The leaf sampling (Table 1) showed that the addition of the pre-pink application reduced leaf scab throughout the season. However, the pink, and the 4-week

application also, each had a reducing effect so that the 4-application schedule containing them, but omitting the pre-pink, held leaf scab to less than 5 per cent.

Scab on the fruit at packing time (shortly after harvesting) was reduced by the pre-pink application (Table 2), was increased by omitting the 4-week application, and was not affected by the August application.

TABLE 2.

Comparison of leaf scab, fruit scab, and russeting on experimental Ben Davis, Highmoor Farm, 1926

Schedule[1]	Scab percentages[2]				Fruits at packing[3]		
	On leaves	On fruits					
		On tree 9/23	At packing	In storage	Total	Russeted	Clean[4]
	%	%	%	%		%	%
A	1	T[5]	T	0–T	2960	15	85
B	2	T	1	1	2079	13	86
C	3	T	2	T–1	4697	12	86
D	5	1	2	T–1	3352	11	87
O	24	27	44	3–8	9282	4	52

[1]See Table 1 for applications of each schedule.
[2]On leaves, average of last 4 examinations in Table 1. In storage, range for trees, on part of the scab-free fruits of each count tree. On fruits at packing, based on total grouped fruits of count trees.
[3]Same as those under scab percentages, at packing.
[4]Given as the remainder over the total scabby and russeted. In fact, some fruits (number unrecorded) were both scabby and russeted, so that the actual percentage of clean fruits was slightly greater than is given here.
[5]Trace (T) is less than ½ of one per cent.

Fruits packed in barrels as clean were shipped 50 miles by freight and held in cold storage until in January. Storage scab then was rare on fruits from sprayed plots, the August application having no effect, and was more common though not abundant on unsprayed fruits (Table 2). Artificial inoculations made on the tree from August 23 to October 8 and at packing time had no effects. Evidently the storage scab was initiated before the August application was made. In storage, temperatures of 32-33, 31-32, and 29.5-31° F. gave respectively 11, 8, and 3 per cent scab in parts of one lot, indicating an inhibiting effect from lower temper-

ature under these conditions. However, several other lots when divided and treated similarly showed no such effect. Basket storage had no consistent effect in comparison with barrel storage. Scab lesions evident at the time of packing did not enlarge in storage. The evidence was negative regarding an increase of scab due to handling scabby fruit alternately with clean fruit, or due to clean fruit being packed in contact with scabby fruit.

TABLE 3.

Scab on the leaves of experimental McIntosh on Highmoor Farm, 1926

Schedule	Applications[1] and their dates						Scab on leaves[2]						
	PP	Pk	Ca	2-w	4-w	Aug.	6/16	6/28	7/13	8/12	8/25	8/31	10/6
							%	%	%	%	%	%	%
A	5/18	5/25	6/14	6/28	7/12	------	0	0	0	0	1	1	2
B	------	Do	Do	Do	Do	------	0	1	3	3	5	3	5
C	5/18	Do	Do	Do	Do	8/10	0	0	1	0	T[3]	1	1
O	------	------	------	------	------	------	0	2	9	16	17	11	13

[1]Known respectively as pre-pink, pink, calyx, 2-week, 4-week, and August.
[2]Based on all leaves of a schedule grouped for each date, from 2 or more trees per schedule.
[3]Trace (T) is less than ½ of one per cent.

TABLE 4.

Comparison of leaf scab, fruit scab, and russeting on experimental McIntosh, Highmoor Farm, 1926

Schedule[1]	Scab percentage[2]			Fruits at packing[3]		
	On leaves	On fruits		Total	Russeted	Clean
		On tree	At packing			
	%	%	%		%	%
A	1	0	T[4]	1082	3	97
B	4	0	T	1536	----------	----------
C	1	0	T	1911	----------	----------
O	14	36	58	1807	0	42

[1]See Table 3 for applications of each schedule.
[2]On leaves, average of the last 4 examinations in Table 3. On fruits at packing, based on total grouped fruits of count trees.
[3]Same as those under scab percentages, at packing.
[4]Trace (T) is less than ½ of one per cent.

In 1926 in the McIntosh orchard the 40 fourteen-year-old trees were divided evenly among 4 treatments (Table 3) given

in rotation as the individual trees were met going down each of the two rows. There was no twig infection on these trees.

Here the first scab was found on the leaves of trees receiving no pre-pink application (Table 3), and also more scab was found on these trees throughout the season.

The fruits were scab-free on 22 of the 26 sprayed count trees, and each schedule reduced scab from 58 per cent to less than one-half per cent (Table 4). A single accidental spraying of one check tree at the 4-week application did not prevent its having scab on 57 per cent of its fruit.

Inoculations made as for the Ben Davis gave similar (negative) results.

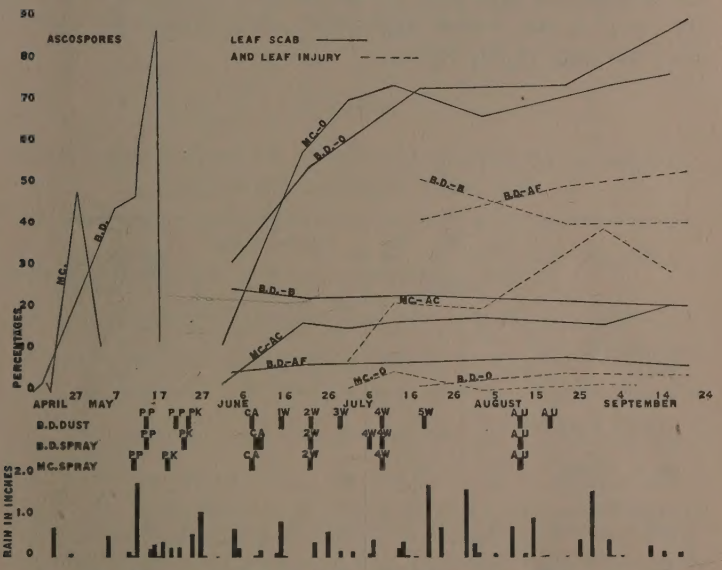

FIG. 12. Season of 1927 on Highmoor Farm. "B. D." indicates data for Ben Davis and "Mc". for McIntosh. At bottom, vertical bars indicate inches of rain on different dates. Above these are shown the times of the applications (PP, Pk, etc.; for meaning of abbreviations see Table 1). Then comes the scale of dates. Above this at the left are lines denoting the percentage of leaves containing identifiable ascospores at different dates. To the right are solid lines denoting the leaf-scab percentages at different dates for certain schedules, and broken lines denoting the leaf-spray injury percentage for the same schedules. For meaning of the schedule abbreviations (-AC, -B, etc.) see Table 5.

In 1927 in the Ben Davis orchard, ascospores were mature in 2-7 per cent of the leaves by April 17-19 and in 51-87 per cent by May 6-16. Discharged ascospores were trapped at the first attempt, on May 12. The pre-pink application where made, on May 14, prevented increase of leaf scab to be found after June 3 (Fig. 12, B.D.-AF). The pink application, made on May 23, did the same in schedule B (Fig. 12, B.D.-B). (For increase in the controls, see Fig. 12, B.D.-O.) An analysis of the individual tree data for succeeding dates of examination, using Bessel's method, shows that the pre-pink and the pink applications significantly checked the spread of the disease on the leaves, except for the trees receiving schedule D (Table 5). A similar analysis for different schedules at each date of examination, shows that in general the pre-pink and 4-week applications each significantly reduced the percentage of leaf scab.

TABLE 5.

Comparison of scab and russeting on the fruits of experimental Ben Davis, Highmoor Farm, 1927

Schedule[1]	No. of plots[2]	No. of count trees[2]	No. of fruits	Scab percentage[3]				Russeted	Russeted and scabby	Clean[4]
				All	"A"	"B"	Cull			
				%	%	%	%	%	%	%
O (no dust or spray)	1	8	2987	91.7	21.6	35.5	34.7	6.9	5.5	6.9
E (sulphur dust[5])	3	15	6630	52.7	29.9	16.7	6.2	16.2	6.0	37.1
D (spray 3 times, pink to 10-day)	2	10	5943	42.1	27.1	10.1	4.8	22.4	6.6	42.2
B (spray 4 times, pink to 4-week)	3	7	2700	31.1	15.5	10.6	5.0	36.6	7.1	39.4
C (spray 5 times, pink to August)	3	13	6616	17.6	8.6	6.1	2.8	20.1	1.2	63.5
A (spray 5 times, pre-pink to 4-week)	2	6	1792	10.2	5.8	3.5	1.0	26.6	1.5	64.7
F (spray 6 times, pre-pink to Aug.)	1	5	3462	5.3	3.2	1.7	0.5	19.1	0.5	76.1

[1]For dates of applications see Fig. 12.
[2]See Chart 1 for location of plots and count (best-yielding) trees.
[3]For definition of degrees of scab see text, p. 153-4.
[4]Determined by first subtracting the percentage of both "russeted and scabby" in the preceding column, from the sum of "all scabby" and "russeted", thus getting the percentage of not clean, and by next subtracting the latter from 100.
[5]For a discussion of the results with dusting see section in the text.

Scab counts made on the fruit on the trees on September 8 indicated considerable reduction in the disease by the pre-pink and 4-week applications together, and some reduction by the August application. Scab counts made after picking in early October, on fruits from the inside halves of the best-yielding trees, kept separate, were made according to the different degrees of infection.

	D		C		A		B		E		C		D	
o	A	D	A	C	A	B	A	C-1	A-1	o	o	o	a	D	o
o	B	E	a	o	a		o	o	o	F	A	D	o	o	o
	C	F-1	B	o	o		B	o	B	G-1	B	o	A-1	o	o
	a	o	o	b	b	o	a	o	a	o	C-1	o	b		o
	o	b	o	o	o	o	o	o	C	o	a	o	B-1		o
	o	o	o	o	o	o	o	o	D	o	o	E	o	o	o
	o	o	o	o	o		o	o	E-1	o	o	o	C	o	o
	o	o	a	b	o	o	c	b	E	D	C-1	B	A	a	o
	o	d	e	o	f	o	o	o	H-1	G-1	o	F-1	o	o	o
	o	B	o	o	o	b	o	a	A	o	A	o	o		o
	o	o	A	o	o	o	A	o	o	o	B	D	o	o	o
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	A	b	C	o	o		C-1	o	B	o	C	b	B	D-1	o
	o	o	o	o	o	o	o	E	o	E	o	o	o	o	o
	o	o		o			o	F-1	C		o	o	C	o	o
	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
		E		A		B		E		C		F		B	

CHART 1. Arrangement of the plots in the 1927 series in the Highmoor Farm Ben Davis orchard. Each capital letter represents a fruit-count tree. Each small "o" represents a non-count tree. Each other small letter (-1, a, etc.) represents a leaf-count tree. The two plots across the middle are permanent untreated controls and extend from east to west. At the top (north) and bottom (south) are the letters indicating the schedules (Table 5).

Scab was graded as of "A" degree when the area of all scab spots was less in the aggregate than that of a circle ¼ inch in diameter. It was graded as of cull degree when the area of all scab spots was more in the aggregate than that of a circle ½ inch

in diameter. Between these two was the "B" degree. These three degrees corresponded to the grading of the season by the State Department of Agriculture and besides were of intrinsic value for recording severity and amount of infection as distinguished from percentage of fruits infected. Such grading of size of scab spots was by estimate, cases of doubt being referred to a card with a series of circles drawn of appropriate sizes. "A circle of a given diameter is only ¼ as large in area as a circle with twice the given diameter. For instance, it would take four circles each ⅛ inch in diameter, or 16 circles each 1/16 inch in diameter, to equal in area one circle ¼ inch in diameter. In our grading of experimental apples, we often detect spots about 1/32 inch in diameter. Such a spot is in grade "A", and is only 1/64 as large as the maximum allowance for the same grade. This is a large variation. However, as will be seen later, it did not result in this grade being excessively large in proportion to the other two grades.

The 30,000 fruits examined are lumped by schedules in Table 5 in the order of decreasing total scab percentages. Comparisons show that there was much more cull scab in the controls in proportion to total scab than in any sprayed lot; that the 4-week application reduced the "A" type of scab; also that the August application reduced all grades of scab and that the pre-pink had a similar effect in greater degree. Analyzing the individual tree records of total scab according to Bessel's method, comparing plot means or schedule means shows that tree variation more than offset the effect of any one spray application except the August one in schedule F but the latter comparison shows that the greater the difference in the number of applications, the more significant was the difference in scab percentage. In other words, the more increase in applications, the more control was clearly evident in spite of tree variation. A similar analysis for cull scab shows that no single application consistently gave significant differences.

Fruits packed in barrels as clean were kept in a cold cellar at Highmoor Farm until in December. The scab found then was less abundant as more spray applications had been made during the summer, with the August application more effective than the pre-pink. Inoculations of fruit on the tree made from September 12 to October 5 gave no scab on 206 fruits, while of 186 control uninoculated fruits 3 (or 2 per cent) developed scab in storage. A record of the order of examination of the different tree lots

had been kept at harvest time. In storage there was no evidence of increase of scab due to following a high-scabby lot with a low-scabby lot, during the October sorting, as against following low-scabby lots with the same kind.

In 1927 in the McIntosh orchard, many leaves contained mature ascospores at the delayed dormant stage. The control trees became black and defoliated early by scab. In spite of the pre-pink and pink applications there was an increase in leaf scab from June 1 to 20 (significant according to Bessel's method used on the individual tree records). (Fig. 12, MC.-AC. See MC.-O for controls.) There was a somewhat greater increase in leaf scab with the omission of the pre-pink application.

TABLE 6.

Results from sorting McIntosh fruits in 1927 at Highmoor Farm[1]

Schedule[2]	Number of apples						
	Total	With scab at harvest		Clean at harvest	Storage scab		Final scab %
		of all degrees	of cull degree		In % of stored	In % of harvested	
		%	%	%			
A (spray 5 times, pre-pink to 4-week)	1395	18.3	11.3	81.7	26.3	21.5	39.8
B (spray 4 times, pink to 4-week)	1627	35.6	27.4	64.4	27.7	17.8	53.4
C (spray 6 times, pre-pink to August)	1411	17.6	12.5	82.4	5.1	4.2	21.8
O (no spray)	335	100.0	100.0	0	------	------	100.0

[1]Fruits lumped for each schedule.
[2]For dates of applications see Fig. 12.

The fruits of the control trees were all cull-scabby and mostly dropped off. The omission of the pre-pink increased fruit scab, both total and of cull grade. (Table 6.) Using Bessel's method on individual tree records, the addition of both pre-pink and August applications, but not of either alone, influenced scab (total and cull) more than tree variation. As in the Ben Davis, even the shortest spray schedule clearly had a dominant or significant controlling effect as compared with the controls. An analysis by

Student's method (16, 17)[4] gave results agreeing with those of Bessel's except to give a significant decrease in cull scab by the pre-pink application.

Fruits packed in baskets as scab-free were stored with the Ben Davis and showed a decided benefit from the August application (Table 6).

On Leaf Burning

When the leaves were examined for scab (see preceding section) notes were made of burning. In the Ben Davis orchard in 1926, burning was decreased by the omission of the 4-week application. Any schedule, and the advance of the season (even in the controls) increased burning which, however, was not severe. In the McIntosh orchard in 1926, burning was increased greatly by spraying, was not decreased by the omission of the pre-pink application, was increased by the August application, and was increased by the use of a gun from which a wide, misty spray-cone could not be obtained easily.

In the Ben Davis orchard in 1927, burning was increased significantly by any schedule, by the 4-week application, and by the August application, according to an analysis of the individual tree records by Bessel's method. The same is true of the McIntosh orchard in 1927.

On Fruit Russeting

When the fruits were examined for scab at packing time in 1926, records were made as to such russeting as covered a fifth or more of the fruit's surface with the net, spot, or solid even types, or such as covered an area as large as a dime with the solid uneven type (See 6, p. 176, and Figs. 21, 22, and 23). The results are included with those on scab, in Table 2. With more applications there was more russeting. In the McIntosh orchard in 1926 there was little russeting with any spray schedule (Table 4).

In the Ben Davis orchard in 1927, russeting or fruit spray injury was counted against a fruit if ⅓ or more of the surface was net-russeted (6, Fig. 22) or if an area as large as a circle ¼

[4]Reference is made by number to "Literature cited" at the end of this bulletin.

inch in diameter was solid or rough russeted (6, Fig. 23). Here russeting when studied by Bessel's method was shown to be increased significantly by any spray schedule but not by the pre-pink, 4-week, or August application alone. In the McIntosh orchard in 1927 there was no russeting worthy of record.

ON PERCENTAGE OF CLEAN FRUIT

In general in the Ben Davis the scab percentage decreased and the russet percentage increased with more spray applications. However, these two trends are not necessarily equally compensating in any one season. In 1926 and 1927 the control of scab outran the production of russeting. In 1927, using Bessel's method of analyzing individual tree records, a significant increase of clean fruit resulted from the use of any spray schedule and from the addition of either the pre-pink or August applications or both.

DIFFERENCES BETWEEN SEASONS

In the Ben Davis orchard two rows were unsprayed in 1925 and 1926 and in 1926 showed no difference, in general appearance, from unsprayed plots that had been sprayed in 1925. Here any spray injury occurring in 1925 had no apparent persistent effect.

Much has been said about the injurious effect of lime-sulphur spraying and its cumulative effect. In 1927, 2 plots were receiving a 5-application schedule of lime-sulphur spray for the fourth consecutive season and 2 for the third. Three plots were receiving a 4-application schedule for the fourth consecutive season. Other plots had received spray for fewer consecutive seasons, and 4 received no spray in 1926 or 1927. Yet there was no apparent difference in vigor to correspond to these differences in spray treatment. This is an orchard 35 to 40 years old, which for various reasons is not especially thrifty. Therefore no conclusion can be drawn here as to the effect of lime-sulphur spraying on the growth of a vigorous set of trees, but at least such spraying is not injurious enough to Ben Davis to hurry the demise of somewhat static trees. In 1927 a large corner of this orchard became defoliated early, regardless of spray treatments present or past.

The foregoing does not apply to young and growing McIntosh or to an orchard all given the same treatment, in both of which,

as will be shown later, spraying has a distinctly beneficial cumulative effect at least in comparison with absence of spraying in similar orchards. Further comparisons were made for the 1925 and 1926 records of certain trees. Not only was there much fruit scab in 1926 where there was little in 1925, but the tree that had the most in 1925 did not have the most in 1926, though still untreated. Regarding russeting, also, there seems to be no correlation between the records of the two seasons, even for the trees untreated in both years. A comparison of the 1926 and 1927 records of the same trees showed with the same spray schedule an increase in fruit scab percentage from 1 to 30, 2 to 7, 1 to 19, 1 to 12, 3 to 7, and 1 to 5, due to greater general severity of scab in 1927.

FINANCIAL PROFITS FROM EXTRA SPRAY APPLICATIONS

In a preceding bulletin (6, p. 181) it was estimated from the available expense data that dry lime-sulphur applied four times in the Ben Davis orchard would cost about 45 cents a tree, and that the addition of the pre-pink application would add about 10 cents to that cost. With an accompanying increase of only 1 per cent of clean fruits (Table 2) this extra cost probably did not pay for itself in 1926. That is, assuming a yield of 1000 apples per tree, it probably was not worth 10 cents to change 10 apples from scabby to clean. The same can be said of the addition of the August application, with the same change in the percentage of clean fruit. Further, omitting the 4-week application was accompanied by no change in the percentage of clean fruit and so can be regarded as a gain or saving of about 10 cents per tree.

On the other hand, in this orchard in 1927 such differences in schedules reduced the amount of scab usually over 10 per cent, absolutely, and still more relative to the amount in the basic schedule (Table 5). Such a change of 100 apples for a 2-barrel tree from scabby to non-scabby probably repaid well the 10 to 15 cents required for each additional application.

In the Ben Davis orchard in 1927 there was not a thinning of fruit and increase in fruit size, as proven in a previous season (23, p. 126, 152-155). Otherwise no test of this point could be made.

COMPARISON OF BEN DAVIS AND McINTOSH REGARDING SPRAYING

On the same experimental farm in 1926 rather old Ben Davis had more leaf scab than young McIntosh, had less fruit scab, and had more fruit russeting. The same is true of 1927 except for leaf scab being the same. Evidently McIntosh need more spraying and can tolerate more with regard to the appearance of the fruit. The same is shown for the leaves by a comparison using Bessel's method on individual tree records.

In a recent list the McIntosh is classed as very susceptible to scab and the Ben Davis as moderately susceptible. (29, p. 4.) In another list for Ohio conditions both are called very susceptible to scab while Ben Davis is called very susceptible to spray injury of fruit or foliage while McIntosh is called slightly susceptible. (38, p. 6.)

SULPHUR DUST ON BEN DAVIS IN 1927

With the spray plots were included three sulphur dust plots. The dust (Kolodust and Kolotex) was applied in "split applications" (at the rate of ¾ pound per tree from one side, the same amount being put on from the other side the next time) and 11 applications were made during the season. As to leaf scab, the dust plots in general were more nearly like the untreated plots than like the 3-application spray plots. These disappointing results can be attributed to a possible insufficiency of power in the engine used, to inexperience on the part of the operator in the application of dust, to inefficiency of the dust as a fungicide, or to lack of adherence of the dust in the frequent rains of the season.

Individual tree records were used with Bessel's method for further comparisons. Leaf scab was reduced only after June. Leaf injury was less than in the spray plots. Fruit scab was reduced more than leaf scab. There was significant decrease of total and cull fruit scab and significant increase in russeting and in clean fruit percentage, but not as much as with spray. Scab appeared in storage.

RELATIONSHIP BETWEEN LEAF SCAB AND FRUIT SCAB

In our experiments probably most of the fruit scab came directly from the scab spots on the current season's leaves. In the McIntosh orchard in 1926 the greater percentage of leaf scab in the schedule with the pre-pink application omitted, had no effect on the fruit scab. However, the leaf scab percentages of the untreated trees are arranged in Table 7 in the order of increasing amount, to see whether there is a correlation with the amount of fruit scab. In only 3 of the 10 trees is the order different, and in the first and last exceptions the fruit percentage is only one place out of order. This indicates that the amount of leaf scab determined to a great extent the amount of fruit scab. The correlation coefficient is both important and significant, being $.892 \pm .044$. (For method of calculation see 35, p. 8, and 2, p. 53.)

TABLE 7.

Comparison of leaf scab and fruit scab of individual unsprayed McIntosh trees, 1926, listed in order of increasing percentage of leaf scab

Row	Tree	Leaf scab	Fruit scab at packing
		%	%
N	2	4	15
S	8	6	7
S	4	11	28
S	20	12	45
N	14	13	57
S	12	16	58
S	16	18	29
N	6	20	66
N	18	24	91
N	10	25	86

In the same orchard in 1927, the omission of the pre-pink application increased the fruit scab much more than the leaf scab.

VARIATION BETWEEN TREES OF THE SAME PLOT

In the Ben Davis orchard in 1926 the fruit scab percentage for individual unsprayed trees ranged from 26 to 60 per cent. Here the indications are that in new control plots, proximity to permanent control plots increased the leaf scab somewhat without influencing the fruit scab. Here in 1927 in spray and dust plots there was no such effect of proximity on leaf or fruit scab.

In Ontario the summer spores were caught on glass slides up to a distance of 75 feet from diseased trees. (12, p. 562.)

In the McIntosh orchard in 1927 there was no apparent correlation between fruit-scab percentage and position in the row except with schedule B, which showed a consistent or progressive increase from the middle to the west end, the correlation coefficient being $.958 \pm .023$, both important and significant. (For method of calculation see 35, p. 8, and 2, p. 53.)

AMOUNT OF NITRATE OF SODA FERTILIZER AND SCAB

Different amounts of nitrate of soda as a fertilizer on Ben Davis were being tested, as described in Bulletin 322 (31, p. 4), in an orchard sprayed uniformly but not included in the spraying experiments here recorded. Leaf samples (individual tree records analyzed by Student's method) and fruit examination in 1927 showed that location rather than amount of nitrate determined the scab percentage.

TWIG INFECTION AND SCAB IN McINTOSH

Copper sulphate (blue vitriol) 5-50 solution (5 lbs to 50 gals.) was applied to alternate trees in two infected rows of young trees at Highmoor Farm in early October, 1925. Observations made at this time and later showed that most twig infection but not all is obvious in the autumn. As in preceding years, the twig lesions infected the nearby leaves later than the first ascospores and no earlier than the first leaf-borne summer spores. Their effect therefore is distinct only when ascospore infection is small in amount or when it is reduced by early spray applications. In

this test there was some evidence that spraying reduced the increase from fall to spring in the number of evidently infected twigs and reduced their capacity to infect nearby leaves, but the effect was too small to be proved or to make the spraying worth while.

In early May, 1926, a similar test with 16-50 dry lime-sulphur spray mixture was made on Highmoor Farm, with results as discouraging as those got with the copper-sulphate solution.

In 1926 in an orchard near Orono, in spite of pruning of infected twigs and spraying (5 applications) which reduced ascospore infection, several trees showed severe infection near unpruned infected twigs. In this orchard during the preceding fall some trees were sprayed with a copper sulphate 15-50 solution. On May 1, 1926, washings of the twigs gave no positive test for copper and lesions on them produced spores giving a high germination test (75 per cent).

On June 25, 1926, a McIntosh orchard that had been sprayed four times was examined in Hampden. Only one diseased leaf was found. Twig infection was known to be abundant in this orchard. In August, scab had become bad, with twig lesions apparently the cause. By September 20, scab counts gave over 30 per cent on the leaves and over 60 per cent on the fruits. These observations show that, as in the orchard near Orono, spraying and freedom from scab up to July 1 by no means gives assurance that in the presence of twig infection there will not be severe scab injury late in the summer.

In the course of a limited amount of survey examination of commercial McIntosh orchards, 12 were found to have twig infection present and 13 were found to be free. In the latter instances sometimes it was in other nearby McIntosh orchards or trees. The percentage of leaf scab found was 23 per cent on the average for the former and 13 per cent for the latter. The fruit scab percentage was respectively 80 and 19 per cent. At least there was an association between twig infection and greater amounts of leaf and fruit infection. In the light of the preceding sections of this bulletin, it seems probable that this association was due to a cause-and-effect relation. This relation often was brought out by the proximity of groups of infected leaves to twig pustules. It would seem that special measures to remove twig infection from McIntosh would be justified, and is needed in a fair-sized

proportion of even what are considered to be good commercial orchards. This is one of the problems without a proved solution.

In 1927 on Highmoor Farm a delayed dormant 5-50 liquid lime-sulphur application did not affect the capacity of infected twigs to act as sources of leaf infection. Over 80 per cent so acted. In some instances the twig pustules were still unbroken on June 13.

This season, the Orono orchard showed a great inprovement but not the one at Hampden, the difference possibly being due to the pruning in the former.

ORCHARD SURVEY DATA, 1926

In the 25 commercial McIntosh orchards mentioned in the preceding section of this bulletin with reference to twig infection, over 12 systems of spraying or dusting were followed. Just how many, could not be determined with certainty due to lack of careful records by some of the growers. In a general survey of the Maine apple industry as many as 130 different spraying or dusting systems are recorded (21, p. 180). Although our records show a tendency for more scab with fewer applications, there are too many systems, too few orchards, and too many other complicating factors such as concentration, pressure, and thoroughness, to permit any definite conclusion.

SCAB CONTROL EXPERIMENTS IN COMMERCIAL ORCHARDS

Experiments and observations were made in a limited way in several commercial Baldwin and McIntosh orchards in 1927. The leaf-scab percentages are summarized graphically in Fig. 13. Here it will be seen that in the HJ and RM orchards there was much more scab without spray than with it. This shows that scab inoculum either as ascospores or twig infection was present and that spraying was effective in reducing infection by it. There was less difference than this between sprayed Baldwins and untreated, and between sprayed McIntosh and untreated, in the SW orchard, and between dusted and untreated trees of the same two varieties in the CH orchard. This can be attributed to the poor

equipment used in the former and to the discontinuance of dusting, following a hailstorm, in the latter.

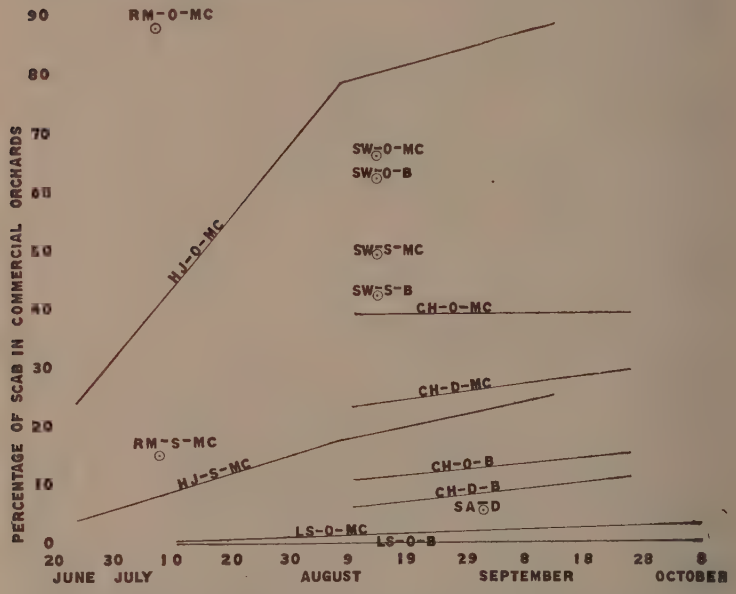

FIG. 13. Season of 1927 in commercial orchards. Lines and encircled points represent leaf scab percentages on different dates. Each is designated first as to orchard, next as to whether sprayed (S), dusted (D), or untreated (O), and finally as to variety, Baldwin (B) or McIntosh (Mc.)

An interesting and important point is brought out by the data on the LS orchard, where unsprayed Baldwins and McIntosh showed practically no leaf scab. Here such apparent lack of need of spray should be attributed to lack of inoculum due to extreme thoroughness of spraying in the two preceding seasons. The owner claimed to have sprayed 13 and 8 times respectively in those seasons; it is known from observations made by ourselves that his control was very effective in 1926; and scab was abundant in 1927 on trees in a neighboring orchard showing that seasonal conditions were favorable to the development of the disease providing it could get a start. Here the fruit from an untreated McIntosh tree that had a leaf-scab percentage of 4, was 34 per

cent scabby, of which 12 per cent was of cull grade. The orchard run of fruit from sprayed trees was about 3 per cent scabby.

In the orchards that showed much reduction in leaf scab by fungicidal treatment, as judged from unsprayed orchards in the vicinity, either no untreated control trees were present, or they soon became so scabby that the owner would not permit further omission of treatment, or the owner did not make it possible to examine the fruits from different treatments separately. Hence data on fruit scab are not available.

The facts of the preceding paragraph, together with the wide variation previously shown to exist between different orchards due to differences in past treatment, method of spraying, etc., make it possible to hope only for the discovery of possibilities by means of the more accurate experimental tests made on Highmoor Farm. If the orchard growers of this State are to make rapid progress in a general improvement of their understanding of the most advisable procedure regarding apple scab, they probably will have to coöperate in various ways. Some promising ways that may be suggested for trial are accurate records by growers as to their equipment, applications, etc.; accurate grading records made according to a uniform system and compared with the growers' records; spray rings bringing efficient similar fungicidal treatment to orchards of different kinds and so permitting the study of the effect of various conditions on the fungicidal treatment; reliable records on the development of the scab disease with a scattering of representative orchards used in part for experimental tests.

RELATION OF ASCOSPORE DEVELOPMENT TO VARIOUS CONDITIONS

In the first section of this bulletin it was shown that the ascospores might develop early enough to make a pre-pink application effective in reducing scab, but that the development might vary with location and season. A 5-50 copper sulphate solution applied before leaf-fall in late October, 1925, apparently did not reduce the amount (small normally in 1926) of ascospores found in 1926, in Ben Davis at Highmoor Farm. Ascospores were also found in McIntosh leaves, said to have been copper-sprayed, re-

ceived from an apple grower. At present no practical method of reducing ascospore deevlopment can be recommended. Therefore the most important thing to do about ascospores is to determine their development, assuming that their abundance in a mature state creates a menace. The hope has been expressed that in time the conditions favoring ascospore development would be known and determined by apple growers, but the results of recent studies have demonstrated greater complexity for the problem than was expected. At present direct microscopic examination is required and such examination shows considerable variation with season, location, and time.

For example, on May 17, 1926, of 35 Ben Davis leaves, only one had mature ascospores and these in only one ascus. In 1927 in the same orchard, two to 7 per cent of the leaves contained mature ascospores on April 17 and 19, and from 51 to 87 per cent on May 6 to 16. On the same farm, in 1927, in contrast to these Ben Davis, in McIntosh the abundance was past its peak, many having been discharged, by May 3 so that only 20 per cent of the leaves contained them. In McIntosh in another locality, development of ascospores occurred several weeks earlier yet (probably due to earlier melting of the snow) both with respect to the calendar dates and the growth of the leaves.

In 1927, ten lots of leaves were divided each into two sublots, one showing lesions or scab spots of the preceding summer and the other not showing such lesions. In one pair of sublots no ascospores were found, but in the other 9 pairs a higher percentage of leaves contained ascospores in the sublot showing the summer lesions.[5] Grouping the leaves of these two series of sublots, 19 per cent of the 245 scabby leaves had developed ascospores but only 3 per cent of the 145 apparently clean leaves. This difference in favor of the obviously scabby leaves was not due to the time of examination, as the proportions of scabby leaves in these samples and the percentage of leaves containing ascospores were not correlated with an advance in the season.

[5]According to Student's method (16; 17) the odds are 262 to 1 for significance regarding the percentage of leaves with mature ascospores, and 555 to 1 regarding the percentage with ascospores mature or immature.

DISCUSSION OF CHIEF RESULTS AND PROBLEMS

The basic problem, as we see it, is how to enable the apple grower to secure the most *satisfactory* control of apple scab. (This may not mean the most *effective* control, as costs, convenience, and spray injury are involved.) This problem can never be solved finally as long as there are continual changes in the conditions that affect apple growing. However, it is possible to make progress in certain phases of the general problem, thus enabling apple growers to approach closer to a satisfaction of their own desires as to scab control. Such progress also should enable apple growers to meet more effectively the competition of growers of other regions and of other kinds of fruits. Through the latter they will, perhaps involuntarily, help raise the quality of fruits in general that are offered for consumption.[6]

SEASONAL AND LOCAL MODIFICATION OF GENERAL FUNGICIDAL SCHEDULE

A general fungicidal schedule to be followed against apple scab, is available for the whole apple-growing area both of this country (29) and of this State (7). As explained in a previous bulletin in 1925 (23, p. 184), a "general standard [schedule] can be expected to give only general or average results", and each season and locality or even orchard actually differs from others as to the value of one or another application, kind of material, type of equipment, etc. The truth of this has been proved. It therefore seems logical to try to fit the efforts to meet the needs. The difficulty, however, remains that it is still impossible to foretell accurately when and where a given condition will be especially important. At present an apple grower who wants an improve-

[6]Oranges, grapefruit, and grapes offer the most competition to apples (10, p. 35) though "the increase in commercial canned berries, cherries, pears, peaches and apricots also has had a tendency to decrease apple consumption" and "the supply of fresh fruits and melons in all important retail markets throughout the entire season is not without its effect" (28, p. 4). "On the Boston market Maine apples do not bring the prices that are paid for apples from the other parts of New England." Here "throughout the year bananas and oranges are the strongest competitors of apples," but there is also competition from strawberries, peaches, and cantaloupes. (13, p. 7.)

ment on the general schedule has the choice of three general alternatives, (1) to always follow the methods known to be necessary in the worst scab years, (2) to try to experiment either alone or in a group in foretelling the effects of seasonal or local modification of a standard procedure, or (3) to follow the advice of an expert present for the purpose.

In our last bulletin (6, p. 200) it was concluded that "the seasonal adaptation of spraying through expert advice[7] probably is good as far as it goes, but it often does not go far enough because of differences between localities", and some of the complexities of this phase of the problem were listed.

In this bulletin in preceding pages it has been shown that there may be variation even in different orchards on one farm and in different parts of the same orchard, as to the effects of a given treatment. Also, the generally accepted idea that there may be important differences between succeeding seasons in the same orchard, is shown to apply to various phases of the weather, tree development, and the development of the scab fungus.

We therefore must consider these questions, "What must an expert know in order to foretell the need for standard schedule modification in a particular season in a particular orchard?" and, "How many orchards will the expert's time permit him to handle effectively in a season?"

In our opinion the expert should first know how many ascospores per acre are mature. This requires the examination of leaves by means of a microscope with sufficient power to identify these spores, that is, with a magnification of about 200 times and a clear field and with a price of between $50 and $100. The expert must know what leaves are representative but the evidence is small in amount and somwhat conflicting as to what conditions favor the development of the ascospores, so that the expert still has to guess more or less as to what makes leaves representative. Assuming that the leaves are representative, the expert must determine the average number of mature ascospores per leaf, which can not be done without considerable examination, in Maine at least, because of the variation in maturity. If the expert has figures for the

[7]Here this means advice given as to specific applications in specific orchards or localities, based on microscopic examination of leaves for ascospores and on weather forecasting.

average number of leaves per acre and the average number of mature ascospores per leaf, the number of the latter per acre can be estimated with a possibility that the actual figure may be somewhere between half and three times the estimate. Knowing the actual number of mature ascospores per acre at any one time, the value of this fact for prognostication is influenced, according to the available *ex post facto* evidence, by a number of climatic or weather conditions some of which have only begun to be carefully studied in relation to apple scab.

An appealingly simple type of recommendation states that when once mature ascospores are discovered, the next "rainy period" should be foretold and guarded against by a "timely" application of spray or dust, necessarily dust if the area to be covered is large for the number of teams or tractors to be used. This explanation assumes that a few ascospores are as dangerous as many, which some of the best students of the subject do not admit. (The latter claim that all other conditions being equal, few are less dangerous than many.) This simple recommendation assumes that rain is necessary for the release of ascospores and their infection of the leaves. However, several reports record ascospores discharge in the absence of rain (15, p. 7, 8, 11; 3, p. 21-22; 20, p. 220, Table 3; 18, p. 188-190; 19, p. 333). Further, the presence of dew should permit infection, according to results which show that in 30 minutes in drops of water these spores become resistant to removal and that they can penetrate the leaves in 6 hours. (15, p. 28, 29, 40.)

This simple recommendation usually does not explain just what is meant by a "rainy period". In fact, there are all kinds and degrees of rainy periods, and the differences between them are due to several factors each of which evidently has some effect upon the amount of infection caused by a given number of ascospores per leaf. Some of these factors are temperature, duration of period of precipitation, intensity of precipitation, and humidity and sunlight immediately after periods of precipitation.

This simple recommendation requires the forecasting of rainy periods. Presumably this requires the forecasting both of rain and the duration of rain. Within recent years, in a test of weather forecasting, at Washington precipitation failed to occur on 62 of 91 days for which it was predicted, and occurred in excess of 0.01 inch on 46 days out of the 185 for which fair weather was

predicted. With 75 failures, the percentage of verification for the forecasts, made each week 2 to 7 days ahead, was about 73 per cent. (22). Shorter forecasts would be more accurate in Washington than the longer ones, but any forecasts probably would be less accurate in Maine than in Washington because of the greater uncertainty, in this part of the country, of the course of the cyclones and anticyclones upon which the weather predictions are largely based. An examination of forecasts and precipitation records at Lewiston, near Highmoor Farm, has shown an accuracy of 60 to 75 per cent for one-day forecasts.

This simple recommendation, by not defining a rainy period, does not have to meet the difficulty of deciding what should be done when there is a frequent occurrence of what may be called rainy periods. In our experimental orchard in 1926, ascospores were mature by May 17, there were only two consecutive rainy days (June 1-2) between May 13 and June 7, yet by June 10 3 per cent of the leaves were scabby in unsprayed plots. With the frequently demonstrated incubation period of about 2 weeks, this means infection before June 1, or without what we would call a rainy period. On the other hand, by July 13 over ⅕ of the leaves had become infected though only one more pair of consecutive rainy days had occurred up to July 8. Waiting for the approach of rainy periods before spraying, this year would have been disastrous, as we define rainy periods, if we could have foretold them. If on the other hand we accept a rainy day as a rainy period, we had enough rainy days to show that it is not at all necessary to precede each rainy day with spray in order to get good control.

The simple recommendation that has been analyzed, does not give due consideration to the fact that fungicides can reduce infection even after ascospore discharge, that thorough applications at regular intervals regardless of the forecasting of rainy periods, can and do control scab, and that the nature of the season may reduce the threatened effect of a heavy ascospore infection or magnify the effect of a light one.

Finally, this simple recommendation has never been accompanied by figures showing how many orchardists were advised to omit or to make an application on the basis of ascospore maturity and weather forecasting, and showing what percentage of the orchardists that followed such advice actually improved their control of scab by making the application, or reduced their costs

without decreasing their control by the omission of the application. (The latter proof would require the orchardist to divide his orchard into a part with and a part without the application in question, and then data on leaf scab and fruit scab would have to be got at the proper times and in suitable ways.) Neither has it been shown that orchardists making use of recommendations based on ascospore discharge and weather forecasting have improved their results because of such recommendations, over results got by following the standard schedule. On the other hand, this simple recommendation often is accompanied by data showing that it is not reliable, or by admission of some of its weaknesses. As an example of the latter, "scab-spore discharge may vary as much as a week in the same county, consequently a large number of trained observers are necessary for such spray service work." (26, p. 36.)

There are good indications that the advocacy of spray service is not based so much on any proof of benefit from definite advice regarding certain applications in particular orchards, as it is based on the acknowledged value of general educative progress involved with the giving of general advice on various phases of apple pests and diseases.

In Michigan it is suggested that instead of trying to reduce the absolute cost of spraying per tree by eliminating some applications, it will be better to reduce the cost per bushel or the relative cost per tree through increasing the yield per tree. (9).

In conclusion, then, it seems to us that even the experts who can explain why apple scab infection *has* occurred in a given place and season, have not presented the proof that they could *foretell* it well enough to give results in practice; that if they could, the situation is complex and variable enough to require "a large number of trained observers" in an apple producing region if reliable advice is to be given; and that the best advice is to follow the general schedule if general results are wanted, and to follow the safest known schedule if the best results are to be assured. (The latter, on McIntosh on Highmoor Farm, is at least six applications, pre-pink, pink, calyx, 10-day, 4-week, and August. Even this may require some change as our experience accumulates.)

STORAGE SCAB

In our last previous bulletin we expressed our inability to make a definite statement as to the time of infection by scab appearing in storage. (6, p. 198-199.) In the preceding pages of this bulletin it has been shown that in seasons when severe it is chiefly, if not entirely, due to late infection on the tree and that it is reduced by a late (August) application at least under certain conditions.

In Canada "a special application of fungicide about a month or six weeks before harvest is found to materially protect the fruit from late scab infections as well as sooty blotch and other diseases which may appear in storage." (11, p. 7.)

In Indiana in 1923 "owing possibly to the cool wet August there was considerable late fruit infection, much of which developed in storage in the shape of jet-black lesions or jet-black extensions from field lesions". (8, p. 299.)

In Illinois in a Grimes orchard, infection has been observed in late August or September in two seasons. (1, p. 286.)

In Virginia a period of infection has been found to occur late in the summer, appearing about October 1 as of the "pinhead" type. (32, p. 9.)

In Vermont in 1900 the storage form of scab developed immediately after storage in barrels, except on windfalls picked up on September 12. Possibly infection occurred after September 12, but it also seems probable that infection occurred before September 12 and removal from the tree stopped the development of the lesions. The account states that the development of the lesions was favored also by shade and poor ventilation and probably by excessive moistness of the weather of the last half of September. (14, p. 235-237.)

In very recent years there has arisen the problem of arsenical residues. Even with no arsenic present, it is to be expected that any apparent residue will now excite suspicion and cause trouble. This fact is unfavorable to the use of an August application for controlling storage scab unless either a washing process is made necessary by the late use of an insecticide against the apple maggot or unless the profit from control of storage scab will more than pay for the August application and the removal of visible residue.

In New York "the immersion of apples for one minute in a solution containing 1 part of hydrochloric acid in 500 parts of water removed spray residue satisfactorily at an expense of about 1 cent per bushel for labor and material. Washed fruit did not deteriorate more than unwashed fruit during nine months in cold storage." (34, p. 36.) A letter of inquiry sent to New York brought the information that "Removal of visible residue from lime-sulfur, Jersey-mix, and bordeaux sprays . . . is accomplished by a few seconds immersion in 1-500 acid . . . We use open slatted orchard picking crates, with which a man can treat two hundred bushels in one-half day. Rinsing with water removes the deposit of calcium chloride formed by the lime on the fruit and is desirable. If the calcium chloride is not removed, under high humidity stored fruit collects moisture."

TWIG INFECTION IN MCINTOSH

In our last bulletin it was stated that "one cause of severe scab infection of McIntosh frequently is twig pustules". (6, p. 147.) In the preceding pages of this bulletin we have presented further evidence of this, including data from commercial orchards. We have also indicated that the pustules sometimes may not break out with summer spores until well along in spring or summer, that they may result in the killing of the twigs in addition to the infection of the leaves, and that control in a susceptible variety, if possible, depends mostly upon pruning, spraying, and seasonal immunity to infection.

In Nova Scotia it is believed that the twig lesions may serve as sources of infection in the early spring, and may also be the means of entrance by canker-producing fungi. (11, p. 3, 5.)

In Ireland the symptoms of twig infection are most obvious in the following spring, when the fruiting pustules of the fungus break through the bark. This "provides an important source of the first infections in Spring." Pruning is advised as a control measure. (24, p. 270.) Tests made in Ireland of a tar-oil winter spray, while serving its purpose in other respects, failed to have any effect on scab infection. (33, p. 303.)

In England scab infections of the leaves may start from diseased twigs as well as from the ascospores (30) and diseased twigs may cause further harm by becoming infected with cankers (36; 37.)

In East Anglia, England(?), "evidence appears to show that there is more twig infection on the heavier than on the lighter soils", and "that soil, climate, and aspect have a greater effect upon the incidence of scab than variety" (27, p. 1119.) Winter spraying, presumably against the twig lesions as sources of spring infection, with tar-distillate wash 10 per cent had no effect as an October application but "appears to have reduced the scab somewhat" when applied in March. The same is true of a solution of soft soap and soda 1 per cent of each. Neither application had any effect with copper sulphate 1 per cent, which is about equivalent to a 4-50 preparation in our terms. (27, p. 1125.)

It is of interest to note that a closely related species of fungus[8] causes the scab disease of pecan and as some symptoms produces twig lesions. "In an endeavor to eliminate the twig lesions as sources of the early spring infections, Bordeaux mixture containing 8 pounds of bluestone and 8 pounds of stone lime to 50 gallons of water and lime sulphur solution prepared by adding 6 gallons of the concentrated solution (32 to 33° B.) to 42 gallons of water have for three successive years been applied as dormant sprays. The time of application was in all cases delayed until a few days before or even after the buds begin to swell. While it appears that a strong fungicide would kill the hold-over stromata, only slight evidence has been secured by the writer favorable to the use of the winter spray." (5, p. 327.) While one report advocates a dormant application against pecan scab, no comparisons are described in it as to the presence *vs.* the absence of such an application. (25.)

Comparative Needs and Tolerances of McIntosh

Most of the previous Maine Station bulletins on apple scab (see p. 145, footnote[1], for a list) have been based on results with Ben Davis. According to results given previously in this bulletin, on Highmoor Farm the McIntosh variety needed more spraying and could stand more, than the Ben Davis. Although the comparison was not so trustworthy as it would be with the location and tree size alike for the two varieties, the absence here of the

[8]Apple scab is caused by *Fusicladium dendriticum* (summer stage) or *Venturia inaequalis* (winter stage) while pecan scab is caused by *Fusicladium effusum* (*Cladosporium effusum*, 4).

rather common, aggravating twig infection makes it seem unwise to expect as good scab control without more spraying. The problem of spray injury in McIntosh will not be discussed until later when the results of pertinent experiments now under way are published.

LITERATURE CITED

(1) Anderson, H. W. Apple scab control in northern Illinois. Trans. Illinois State Hort. Soc. 61:282-293. 1928.

(2) Babcock, Ernest Brown, and Roy Elwood Clausen. Genetics in relation to agriculture. McGraw-Hill Book Co., New York. 1918. 675 p.

(3) Bailey, C. F. Dom. Canada Agr. Exp. Sta. Fredericton, N. B. Rpt. 1926.

(4) Demaree, J. B. Morphology and taxonomy of the pecan-scab fungus, Cladosporium effusum (Wint.) comb. nov. Jour. Agr. Res. 37: 181-187. 1928.

(5) Demaree, J. B. Pecan scab with special reference to sources of the early spring infections. Jour. Agr. Res. 28:321-329. 1924.

(6) Folsom, Donald. Apple spraying and dusting experiments in 1925. Maine Agr. Exp. Sta. Bul. 333. 1926.

(7) Gardner, A. K. Fruit spraying and dusting in Maine. University Maine Ext. Bul. 160 (rev.) 1928.

(8) Gardner, Max W. Indiana plant diseases, 1923. Proc. Ind. Acad. Sci. for 1924. Vol. 34:297-313. 1925.

(9) Gardner, V. R. Cutting corners and cutting profits in spraying. Michigan Agr. Exp. Sta. Quar. Bul. 10:88-92. 1928.

(10) Hauck, Chas. W. The apple industry of Ohio. Ohio Agr. Exp. Sta. Bul. 418. 1928.

(11) Hockey, J. Fred. Apple scab. Dom. Canada Dept. Agr. Pamphlet 82 n.s. 1927.

(12) Howitt, J. E., and W. G. Evans. Preliminary report of some observations on ascospore discharge and dispersal of conidia of Venturia inaequalis (Cooke) Winter. Phytopath. 16:559-563. 1926.

(13) Jefferson, Lorian P. The market outlet for Massachusetts apples. Massachusetts Agr. Exp. Sta. Bul. 231. 1927.

(14) Jones, L. R., and A. W. Edson. Report of the botanists. Vermont Agr. Exp. Sta. Rpt. 1900-1901. p. 227-256.

(15) Keitt, G. W., and Leon K. Jones. Studies of the epidemiology and control of apple scab. Wisconsin Agr. Exp. Sta. Res. Bul. 73. 1926.

(16) Love, H. H. A modification of Student's table for use in interpreting experimental results. Jour. Amer. Soc. Agron. 16:68-73. 1924.

(17) Love, H. H., and A. M. Brunson. Student's method for interpreting paired experiments. Jour. Amer. Soc. Agron. 16:60-68. 1924.

(18) Martin, William H. Apple disease control studies in 1926. New Jersey State Hort. Soc. Proc. 1926. p. 185-209.

(19) Martin, William H., and E. S. Clark. Apple-scab studies. New Jersey State Agr. Exp. Stas. Rpt. 1925-26. p. 332-334.

(20) Martin, Wm. H., and E. S. Clark. Apple scab studies. New Jersey Agr. Exp. Stas. Rpt. 1926-27. p. 218-221.

(21) Merchant, Charles H. An economic survey of the apple industry in Maine. Maine Agr. Exp. Sta. Bul. 339. 1927.

(22) Mitchell, C. L. Forecasts for a week in advance based on northern hemsiphere weather maps. Bul. Amer. Met. Soc. 9:101-102. 1928. As abst. in Exp. Sta. Rec. 59:508. 1928.

(23) Morse, W. J., and Donald Folsom. Apple spraying and dusting experiments 1918 to 1924. Maine Agr. Exp. Sta. Bul. 325. 1925.

(24) Murphy, Paul A. Some fungous diseases of fruit trees. Jour. Dept. Lands and Agr. Ireland 25:269-280. 1926.

(25) Neal, D. C., O. M. Chance, R. P. Barnhart, and E. K. Bynum. Spraying experiments for pecan scab control in Mississippi in 1923. Mississippi Agr. Exp. Sta. Cir. 53. 1924.

(26) Ohio Agr. Exp. Sta. Forty-fifth annual report. For 1925-26. Ohio Agr. Exp. Sta. Bul. 402. 1927.

(27) Petherbridge, F. R., and W. A. R. Dillon Weston. Observations and experiments on apple scab in East Anglia. Jour. Min. Agr. (Great Britain) 32:1119-1127. 1926.

(28) Rees, R. W. Apple survey of the United States and Canada. Dept. Agr. Relations New York Central Lines. 1926.

(29) Roberts, John W., and Leslie Pierce. Apple scab. U. S. Dept. Agr. Farmers' Bul. 1478. 1926.

(30) Salmon, E. S., and W. M. Ware. Biological observations on apple "scab" or "black spot" (Venturia inaequalis). Jour. Pomol. and Hort. Sci. 4:230-239. 1925. As abst. in Exp. Sta. Rec. 57:53. 1927.

(31) Sax, Karl. Fertilization of apple orchards in Maine. Maine Agr. Exp. Sta. Bul. 322. 1925.

(32) Schneiderhan, F. J. Apple disease studies in northern Virginia. Virginia Agr. Exp. Sta. Bul. 245. 1926.

(33) Sherrard, O. The winter spraying of fruit trees. Tests with the new tar-oil washes. Jour. Dept. Lands and Agr. Ireland 25:297-304. 1926.

(34) Thatcher, R. W. New York State Agr. Exp. Sta. Forty-sixth Ann. Rpt. 1926-27.

(35) Wallace, H. A., and George W. Snedecor. Correlation and machine calculation. Iowa State Col. Agr. Mech. Arts Offic. Publ. Vol. 23, no. 35. 1925.

(36) Wiltshire, S. P. Canker infection of apple trees through scab wounds. Univ. Bristol Ann. Rpt. Agr. and Hort. Res. Sta. 1922:71-73. 1922.

(37) Wiltshire, S. P. Studies on the apple canker fungus. II. Canker infection of apple trees through scab wounds. Ann. Appl. Biol. 9:275-281. 1922.

(38) Young, H. C., J. S. Houser, and F. H. Ballou. Spraying program for the orchard and fruit garden. Ohio Agr. Exp. Sta. Bul. 393. 1926.

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No. 347. An Economic Study of 93 Apple Farms in Oxford County, Maine. 1924-1927.

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Bulletin 338

MAINE AGRICULTURE. A Statistical Presentation. The information contained in this publication is based upon the Federal Agricultural Census of 1925. It was made available through the cooperation of the Maine Department of Agriculture and is presented in graphic and tabular form, with appropriate explanatory matter. The more important facts disclosed by the agricultural census in Maine in 1925 are given for each town and plantation in the state. For comparative purposes a summary of the 1910 and 1920 censuses, with respect to farms and farm property, is also given. Data with respect to the following subjects are included in the bulletin: Farms, number and acreage, value of land, buildings and machinery. Livestock on farms January 1, 1925, and livestock products in 1924. Acreage and production of principal crops in 1924. Miscellaneous crops, kinds of roads, cooperative marketing. Farm mortgages, farm expenditures, farm facilities.

Bulletin 346

THE FOXGLOVE APHID. On Potato and Other Plants. On account of the demonstrated fact that aphids or plant lice act as carriers of the so-called virus or degeneration diseases of potatoes, the life history of any aphid which occurs on potatoes is important from a practical as well as a scientific standpoint. Bulletin 346 records investigations which determined, for the first time, that the over-wintering eggs are deposited on foxglove plants. This species of aphid, previously recorded only on the potato, has been found to accept a wide range of summer food plants.